STRENGTH VS CRITICAL STRESSES

INTRODUCTION

In the HIPERPAV field validation, condition surveys were conducted and the time and location of cracks in the pavement were documented. The time at which the first crack formed in the pavement was extracted from the strain gage readings.(6) At this time, the theoretical stress components (axial thermal, curling and drying shrinkage) were calculated and were compared to concrete strength.(7) If the stress was greater than PCC strength, a crack formed. This analysis validated the theoretical models.

In this study, the HIPERPAV model will be used to predict all the stresses in the pavement, instead of using the individual spreadsheet programs.

OBJECTIVE

Assess the validity of using the strength approach in the HIPERPAV model to predict pavement cracking. At the time that the pavement cracked experimentally, modeled PCC strength will be compared to modeled stresses (curling, axial thermal plus drying shrinkage) that develop within the pavement. The HIPERPAV model should predict cracking at the same time as was recorded experimentally.

OPTIMIZATION OF PARAMETERS IN HIPERPAV

The following parameters had to be optimized in the HIPERPAV model:

- An important parameter is the time up to which the program should run during pre-processing to extract the maximum temperature.
- Another parameter to determine is to assess whether or not to use the maximum temperature difference at the top of the slab to calculate the axial temperature differential or to average the temperatures through the thickness of the pavement for this calculation.

HIPERPAV Cracking Time Prediction

Typical output of the model is shown in figure 1. For the first 72 h after placement, PCC strength is compared to the stresses in the pavement. For all the modeling runs, the joint saw cutting time is set to 72 h. This allows HIPERPAV to model the pavement as infinitely long. A comparison between the time when the HIPERPAV model predicts crack formation and the time when a crack did form in the experimental slab reveals the accuracy of the HIPERPAV model. HIPERPAV accurately predicts the time of cracking for this case in figure 1.

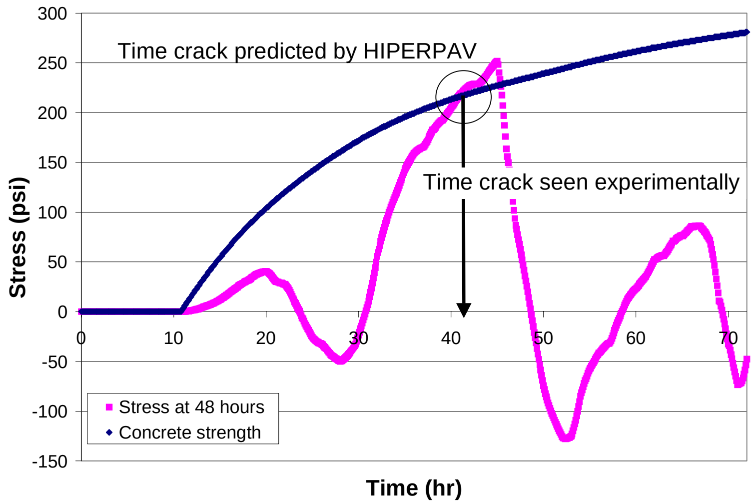

Figure 1. Typical output of HIPERPAV analysis to determine the predicted time of cracking (Pre-processing time = 48 hours, Max temp used for stress calculation in Minnesota slab #2).

Effect of Preprocessing Time on HIPERPAV Analysis

To determine the effect of pre-processing time on the HIPERPAV analysis, the model was run using 24, 36 and 48 hours. As can be seen in figure 2, there is no difference between the stress calculations for 36 and 48-h runs, but there is a decrease in the stresses at the 24-h run for this case. The same plots were made for all other slabs and it is evident that this trend holds. The optimal pre-processing time is 36 h with no loss in modeling accuracy.

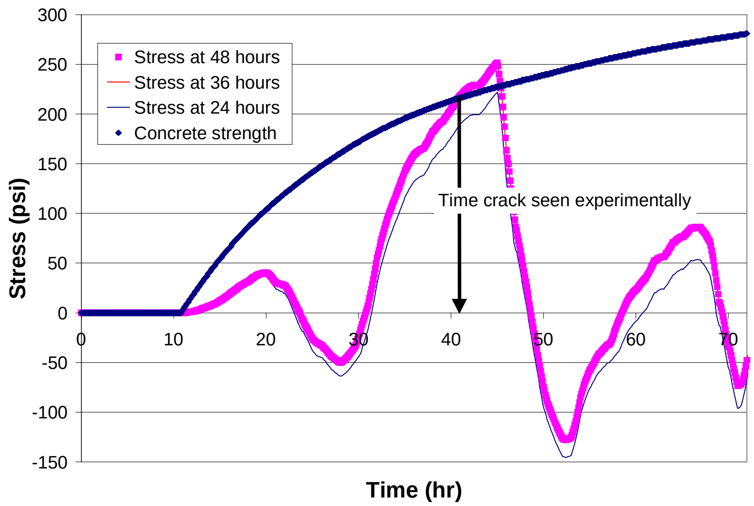

Figure 2. Effect of pre-processing time on HIPERPAV modeling runs. (Max temp used for stress calculation in Minnesota slab #2).

Effect of Temperature Gradient on HIPERPAV Analysis

The effect of temperature gradient on the HIPERPAV analysis was also assessed. It is necessary to know if the analysis is more accurate using the maximum temperature change at the top of the slab or if the average temperature should be used to calculate the axial temperature stresses.

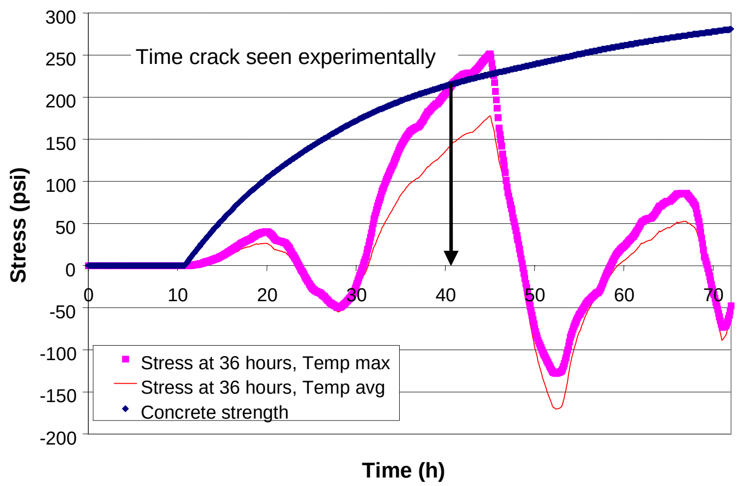

Figure 3. Effect of temperature gradient on HIPERPAV modeling runs with a 36-h preprocessing time. (Minnesota slab #2).

As seen in figure 3, using the average temperature causes the HIPERPAV stresses to decrease. This lower curve does not intersect the PCC strength curve and no crack is predicted to form. Because this analysis is not correct, the maximum temperature gradient will be used to calculate the axial temperature stress.

Comparison Between HIPERPAV Predicted Cracking Time and Experimental Cracking Time

HIPERPAV was run for all of the slabs listed in table 1, and the predicted cracking times were determined. A table that summarizes the HIPERPAV predicted cracking times and the experimental ones is given in table 2. The agreement is good and it is concluded that the present HIPERPAV analysis is capable of accurately predicting the time of crack formation in PCC pavements at early ages. The complete set of stress vs. time curves for all the slabs are included in the addendum.

State	Slab No.	Experimental Cracking Time (h)	HIPERPAV Cracking Time (h)	% Difference between Experimental and HIPERPAV Cracking Times (h)
Arizona	1	21.7	18.5	15
	3	36.4	43.2	19
	5	43.4	43.4	0
	6	38.3	38.3	0
Nebraska	1	16.0	18.5*	16
	2	26.3	39.3*	49
Texas	1	16.1	25.0*	55
	2	14.2	24.0*	69
	3	24.0	15.8	34
	4	14.9	13.5	9
North Carolina	1	13.9	10.1	27
	2	33.8	32.6	4
	3	21.3	16.9	21
	4	37.5	36.3	3
Minnesota	1	43.5	21.7	50
	2	40.7	40.8	0

Table 2. Experimental and HIPERPAV predicted cracking times in PCC pavements (* $\sigma/\sigma_{fc} \neq 1$, time given is when σ/σ_{fc} is closest to 1).

Addendum

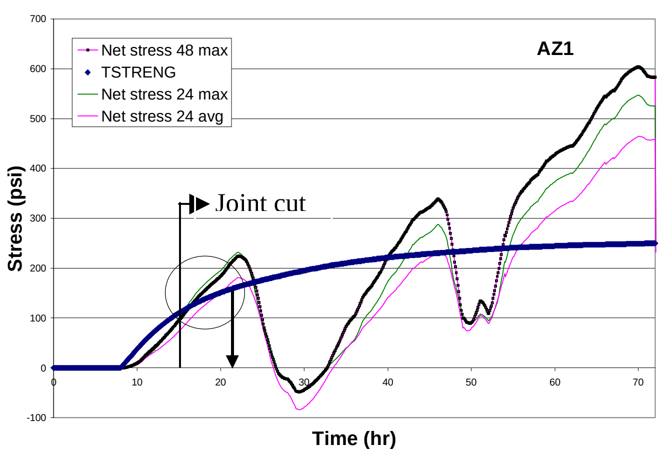

Figure 4. Arizona slab #1.

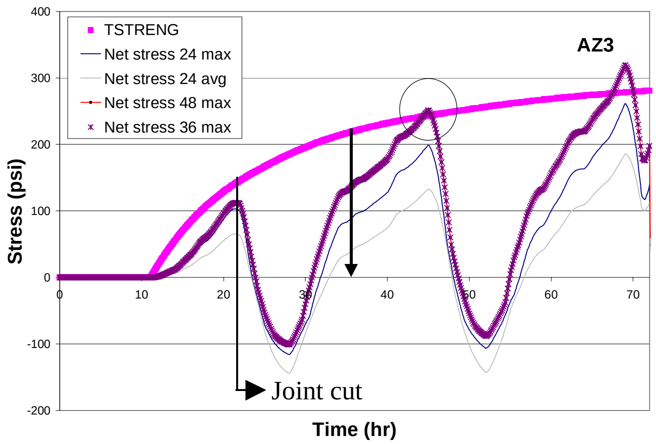

Figure 5. Arizona slab #3.

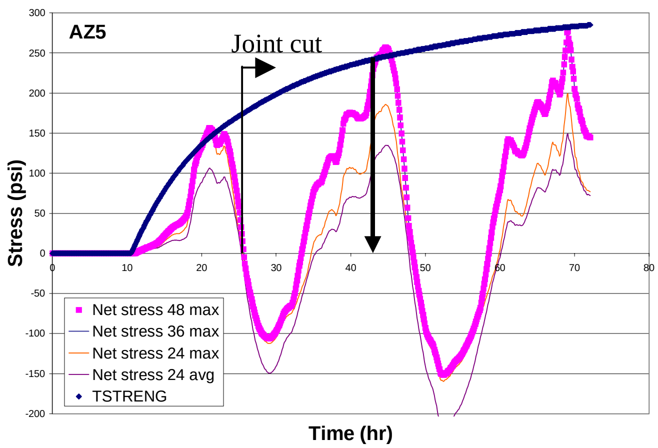

Figure 6. Arizona slab #5.

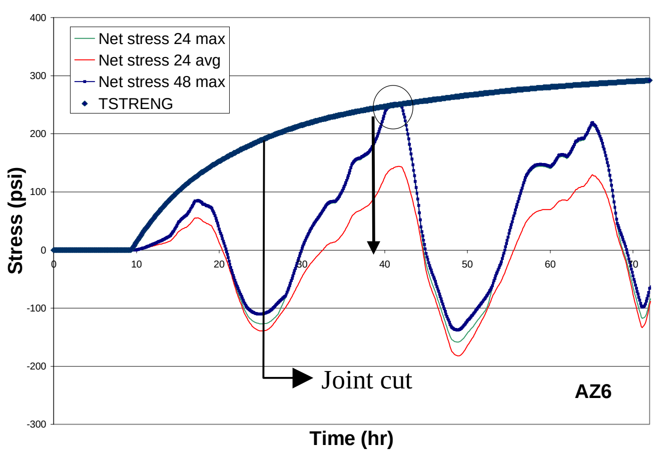

Figure 7. Arizona slab #6.

REFERENCES

(1) Technical Memorandum No. 3, *Field Instrumentation Details and Data Collected - Minnesota Construction Site*

(2) Technical Memorandum No. 4, *Field Instrumentation Details and Data Collected - Nebraska Construction Site*

(3) Technical Memorandum No. 5, *Field Instrumentation Details and Data Collected - Arizona Construction Site*

(4) Technical Memorandum No. 8, *Field Instrumentation Details and Data Collected - Texas Construction Site*

(5) Technical Memorandum No. 9, *Field Instrumentation Details and Data Collected – North Carolina Construction Site*

(6) Technical Memorandum 298007-22, Analysis of Strain Gage Measurements in TX, MN, NE, NC, and AZ Instrumented Slabs

(7) Technical Memorandum 298007-27, Determination of Cracking Stresses in Pavements